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PRINCIPAL DESIGN AND SAFETY CRITERIA

This chapter discusses principal design and safety criteria for structures, systems, and components (SSCs) that protect the public, workers, and the environment from hazards posed by Waste Isolation Pilot Plant (WIPP) operations. For the WIPP, SSCs are categorized as Design Class I, II, and III in the WIPP System Design Descriptions (SDDs). Criteria for the selection of Design Class I, II, and III SSCs are identified in the General Plant SDD (GPDD)[1] and are discussed in Section 3.1, General Design Criteria. Design information for WIPP Design Class I, II, and III SSCs is provided in Chapter 4, Facility Design and Operation.

3.1 General Design Criteria

The mission of the WIPP is to permanently dispose of transuranic waste left from the research and production of nuclear weapons. The WIPP facility was designed and constructed according to DOE Order 6430, General Design Criteria Manual for Department of Energy Facilities, draft, dated June 10, 1981,[2] and codes and standards applicable at the time of construction. Facility modifications designed prior to DOE Order 6430 being superceded were designed according to the revision of DOE Order 6430 and codes and standards applicable at the time of modification. Present and future modifications shall be designed according to DOE Orders O 420.1, Facility Safety [3] and O 430.1A, Life-Cycle Asset Management [4], and all applicable codes and standards as described by the SDDs.

The Department of Energy - Carlsbad Area Office (DOE-CAO) and appropriate regulatory agencies determined that permanent disposal in the WIPP facility protects human health and the environment. The placement of CH waste in the WIPP began in March 1999 and will be for the purpose of permanent disposal with no intent to retrieve. However, if in the future it is determined that recovery of disposed waste is required, prior to commencement of recovery operations: (1) principal design and safety criteria for SSCs that protect the public, workers, and the environment from hazards posed by recovery shall be developed, and (2) those hazards associated with the recovery design and process shall be analyzed and result in a change to this SAR to address recovery.

3.1.1 TRU Waste Criteria

The acceptance criteria of remote-handled (RH) transuranic (TRU) waste to be received and disposed at the WIPP facility is defined in this section. While CH waste has a relatively low surface dose rate, lending itself to direct handling, RH waste surface dose rates require remote handling.

The WIPP shall provide disposal capacity of 6.2 million cubic ft (175,460 cubic m) of TRU waste in TRU waste containers for underground disposal over an operating life of 35 years.

The WIPP shall have the capacity to process up to a maximum of 500,000 cubic ft (14,150 cubic m) of CH TRU waste per year, and 10,000 cubic ft (283 cubic m) of RH TRU waste per year.

The acceptance criteria for TRU waste to be disposed at the WIPP facility, and the basis for the criteria, are presented in the RH TRU Waste Acceptance Criteria[5] (RH WAC) for the WIPP. The RH WAC [5] incorporates five related sets of requirements:

- WIPP Operations and Safety Requirements
- Transportation Safety Requirements for the RH Road Casks
- Hazardous Waste Facility Permit Requirements

- Compliance Certification Decision Requirements

- Land Withdrawal Act Requirements

3.1.2 Facility By-Products

3.1.2.1 Nonradioactive By-Products

The major non-radioactive by-product at the WIPP facility is mined salt. Basic design criterion is the mined salt shall be free of radioactive contamination. Other regulated non-radioactive hazardous by-products shall be handled in compliance with applicable codes and standards.

3.1.2.2 Site-Derived Radioactive Waste

Site-derived radioactive waste shall be treated as radioactive mixed waste unless proof is available that wastes are not mixed. The mixed waste shall be handled in accordance with the Hazardous Waste Facility Permit,[6] as implemented by the State of New Mexico Environmental Department. Because derived wastes can contain only those materials present in the waste from which they were derived and any materials or processes applied at WIPP, no additional chemical analysis of the derived waste is required for disposal. Characterization of derived waste shall primarily be based on information provided by the generator and knowledge of the processes and materials at WIPP.

3.1.3 Design/Functional Classification of Structures, Systems, and Components

3.1.3.1 Design Classification of SSCs

The design classification system shall be used for categorizing SSCs of the WIPP facility, and to determine the proper level of design requirements specified for each SSC. These requirements shall be used to ensure that each SSC will perform its required design function reliably when subjected to: (1) design basis accidents, (2) operating loads, (3) environmental operating conditions, and (4) natural phenomena.

Classification categories shall be identified as Design Class I, II, or III, with Design Class III subdivided into Design Class IIIA and IIIB, as defined in Section 3.1.3.1.1.

Where a single item performs two or more functions, and may be assigned to more than one design classification, the more stringent class shall be assigned. Portions of an item performing different functions may be assigned to different classes if the item contains a suitable interface boundary meeting the requirements of Section 3.1.3.1.2, Design Class Interfaces.

The basic design codes and standards applicable to each class are shown in Table 3.1-1. SSCs are assigned a Design Class on an item-by-item basis, in accordance with the WIPP engineering procedure WP 09-CN3023, Design Classification Determination.[7]

3.1.3.1.1 Design Class Definitions

3.1.3.1.1.1 Design Class I

Design Class I shall apply to SSCs for the prevention or mitigation of the consequences of an accident or severe natural phenomena that could result in a 50-year dose commitment beyond the WIPP Exclusive Use Area in excess of 25 rem (250 mSv) Total Effective Dose Equivalent (TEDE). Currently there are no Design Class I SSCs at the WIPP.

3.1.3.1.1.2 Design Class II

Design Class II shall apply to SSCs that:

- Provide permanent confinement
- Provide permanent shielding
- Monitor variables to:
  - Verify that essential WIPP operational limits are not exceeded
  - Indicate the status of safety system bypasses that are not automatically removed as a part of safety system operation
  - Indicate the status of Design Class I items during all conditions of plant operations
  - Verify that off-normal radiological dose limits are not exceeded following accidental releases of radioactive material

3.1.3.1.1.3 Design Class III

This classification shall be divided into Design Class IIIA and IIIB as follows:

Design Class IIIA shall be applied to those SSCs not included in Design Class I or Design Class II, requiring a different level of quality, beyond that expected in commercial-industrial practice, and includes any of the following functional areas:

- Airborne radioactivity monitoring following accidental releases of radioactive materials
- Major sustained stoppage of waste handling and disposal operations due to failure
- Design and fabrication complexity or uniqueness
- Potential for contamination due to component failure
- Special considerations that are required beyond those contained in nationally recognized codes and standards to ensure the health and safety of operating personnel
- Equipment failure could be of special significance to the health and safety of operating personnel
- Equipment with unique subassemblies, when replaced, shall be identical in terms of function, form, and fit

Design Class IIIB: Class IIIB shall be applied to all other items.

3.1.3.1.2 Design Class Interfaces

When the failure of less-stringently classified SSCs could prevent more-stringently classified SSCs from accomplishing their required function, then one of the following options shall be followed:

- Change the design to preclude consequential failure of the more-stringently classified item.
- Reclassify the less stringently classified item to correspond to that of the more-stringently classified SSC.
- Provide an interface barrier to protect the more-stringently classified SSC.

Exceptions to these criteria shall be addressed on a case-by-case basis and described in the design documents.

3.1.3.2 Functional Classification of SSCs

The SSC functional classifications, definitions, and applicability to WIPP are as follows:

- Safety Class. SSCs whose preventive or mitigative function is necessary to keep hazardous material exposure to the maximally exposed individual (MEI) below off-site risk evaluation guidelines defined in the WIPP RH SAR.
- Safety Significant. SSCs not designated as Safety Class, but whose preventive or mitigative function is a major contributor to defense in depth (i.e. prevention of uncontrolled material releases) and/or worker safety as determined from hazards analysis.

  For WIPP, "prevention of uncontrolled material releases" applies to SSCs whose preventive or mitigative function is necessary to keep hazardous material exposure to a non-involved worker below on-site risk evaluation guidelines defined in the WIPP RH SAR. These guidelines apply to personnel located at 100 meters from a discharge point. As discussed in DOE-STD-3009-94,[8] these SSCs are often not developed based on calculations and do not normally have numerical evaluation guidelines. However, these calculations and guidelines are currently included in the WIPP RH SAR, and are therefore used as the basis for designation of this classification.

  As discussed in DOE-STD-3009-94,[8] a Safety Significant SSC designation based on worker safety is limited to those SSCs whose failure is estimated to result in an acute worker fatality or serious injury to workers. For WIPP, a Safety Significant designation based on worker safety applies to SSCs that prevent an acute worker fatality or serious injury from hazardous material release that is outside the protection of standard industrial practice, OSHA regulation, or mine safety regulation (MSHA).
- Defense in Depth. SSCs that fulfill a defense-in-depth safety function important to accident scenarios that are evaluated in the WIPP RH SAR.
- Balance of Plant. This category includes facility SSCs not identified above. SSCs or functions required by OSHA and mine safety regulation are included in this category.

3.1.3.3 Severe Natural Events

3.1.3.3.1 Design Basis Tornado (DBT)

The DBT is the most severe credible tornado that could occur at the WIPP site as described in Chapter 2. DBT SSCs shall be designed to withstand the highest winds generated by this tornado (183 mi/hr [293 km/hr]), based on a 1,000,000-year recurrence period, and retain their safety function.

3.1.3.3.2 Design Basis Earthquake (DBE)

The DBE is the most severe credible earthquake that could occur at the WIPP site as described in Chapter 2. DBE SSCs shall be designed to withstand a free-field horizontal and vertical ground acceleration of 0.1g, based on a 1,000-year recurrence period, and retain their safety functions.

3.1.4 Decontamination and Decommissioning

Design of equipment and areas within a facility that may become contaminated with radioactive or other hazardous materials shall incorporate features to simplify decontamination. Examples of features to be incorporated are identified in DOE Order 420.1.[3]

The WIPP shall be designed to have the capability of being decommissioned, shall have a documented closure plan, and shall provide for the surveillance, maintenance, and decommissioning of the facility as required by DOE O 430.1A[4] and DOE O 433.1 [9], Maintenance Management Program. The WIPP equipment and facilities in which radioactive or hazardous materials are utilized shall be designed to simplify decommissioning and to increase the potential for reuse of the facilities, equipment, and materials.

References for Section 3.1

1 Waste Isolation Pilot Plant General Plant Design Description (GPDD).

2 DOE Order 6430.1, General Design Criteria Manual for Department of Energy Facilities, June 10, 1981 draft (For reference only, superceded by DOE O 420.1 and Doe O 430.1A).

3 DOE O 420.1, Facility Safety.

4 DOE O 430.1A, Life-Cycle Asset Management.

5 WIPP-DOE-Draft 7-3123, Remote-Handled Waste Acceptance Criteria for the Waste Isolation Pilot Plant.

6 Hazardous Waste Facility Permit No. NM4890139088-TSDF, issued by the New Mexico Environment Department October 27, 1999.

7 WP 09-CN3023, Design Classification Determination.

8 DOE-STD-3009-94, Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports (Change 1, January 2000).

9 DOE Order 433.1, Maintenance Management Program for DOE Nuclear Facilities.

Table 3.1-1, Basic Design Requirements Page 1 of 3

Principal Codes and Standards						
	Typical Equipment	**Applicable Codes & Standards**	**Design Class I (7)**	**Design Class II**	**Design Class IIIA**	**Design Class IIIB**
Structure/ Supports		DBE, DBT, ACI-318, AISC	X	(1), (2)	(1)	
		UBC, ANSI A58.1		X	X	X
		SITE SPECIFIC	(1)	(1)	(1)	(1)
Liquid and Process Air Handling Processing and Storage Equipment	Vessel	ASME VIII, NFPA (5)	X, (6)	X	(1)	(1)
	Piping and Valves Pumps	ANSI B31.1, NFPA (5)		X	X	(1)
		UPC				X
	Pumps	API-610, NFPA (5)	X	X	(1)	
	Storage & Tanks	API-650 or API-620	X	X		
	Heat Exchangers	ASME VIII, TEMA	X	X	(1)	(1)
	All Other Equipment	MFR's STD			X	X
Air Handling Ducting & Fans		ARI, SMACNA, AMCA	X, (3)	X, (3)	X, (3)	X
HVAC Filters	Pre Filters	ASHRAE 52.68	X, (3), (4)	X, (3)	X, (3)	X
	HEPA Filters	MIL F 51068C, ANSI N 509, ANSI N 510	X, (3)	X, (3)	X, (3)	X
Mechanical Handling Equipment	Crane & Related Equip.	CMAA	X	X	(1)	
		CMAA, AISC, AWS	X	X	(1)	
		MFR's STD			X	X
Instrumentation and Electrical		IEEE-NE	X			
		ANSI STDS or NEC	X	X	X	X
		MFR's STD		x	X	X

Table 3.1-1, Basic Design Requirements Page 2 of 3

Principal Codes and Standards						
	Typical Equipment	**Applicable Codes & Standards**	**Design Class I (7)**	**Design Class II**	**Design Class IIIA**	**Design Class IIIB**
Quality Assurance Program		ASME NQA-1 & SUPPLEMENTS	X	X	X	
		COMMERCIAL AND INDUSTRY PRACTICES				X

X - Minimum Requirements

NOTES
(1) Requirements shall be determined on case-by-case basis.
(2) Required for structure and supports needed for confinement and control of radioactivity.
(3) Except structures and supports that are designed to withstand DBE/DBT when specified in column 1 of this table. (See Section 3.2 for specific criteria.)
(4) Underwriter's Laboratory (UL) class I listed.
(5) For fire protection systems.
(6) ASME III for other class I vessels.
(7) Currently there are no Design Class I structures, systems, or components at the WIPP.

Definitions			
ACI-318	American Concrete Institute. Building Code Requirements for Reinforced Concrete (ACI-318-77)	ASHRAE 52.68	American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc. Standard 52.68. Method of Testing Air Cleaning Devices Used in Central Ventilation for Removing Particulate Matter
AISC	Specification for Design Fabrication and Erection of Structural Steel for Buildings	ASME VII	American Society of Mechanical Engineers. Section VIII Division I Pressure Vessel
AMCA	Air Moving and Conditioning Association Fan Performance and Sound Testing Requirements AMCA 210.67 and 300	AWS	American Welding Society
ANSI B31.1	American National Standards Institute, Power Piping	CMAA	Crane Manufactures Association of America. Specification No. 70 Specification for Electric Overhead
ANSI A58.1	Building Code Requirements for Minimum Design Loads in Building and Other Structures	IEEE	Institute of Electrical and Electronic Engineers
ANSI N 509	Nuclear Power Plant Air Cleaning Units and Components	MFR'S STD.	A Commercial Catalogue Item Built to the Manufacturer's Design Standard
ANSI N 510	Testing of Nuclear Air Cleaning Systems	MIL-F-51068C	Military Specification, Fire Resistant High Efficiency Particulate Air Filters
API-610	American Petroleum Institute. Centrifugal Pumps for General Refinery Services	NFPA	National Fire Protection Association

Table 3.1-1, Basic Design Requirements Page 3 of 3

Principal Codes and Standards			
Definitions			
API-620	Recommended Rules for Design and Construction of Large, Welded Low and Pressure Storage Tanks	NEC	National Electrical Code
API-650	Welded Steel Tanks for Oil Storage Atmospheric Tanks	SMACNA	Sheet Metal and Air Conditioning Contractors National Association, Inc
ARI	Air Conditioning and Refrigeration Institute	TEMA	Tubular Exchanger Manufacturer’s Association
ASME-NQA-1	1989 Edition, Quality Assurance Program for Nuclear Facilities	UBC	Uniform Building Code
		UPC	Uniform Plumbing Code. (American Standard National Plumbing Code ANSI A40.8)

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3.2 Structural Design Criteria

3.2.1 Wind Loadings

The design wind velocity for Design Class II structures shall be 110 mi/hr (177 km/hr) at 30 ft (9.1 m) above ground. The wind velocity selected, with a 1,000-year mean recurrence interval, is adopted from the results of a site specific wind and tornado study.[1] The design wind velocity exceeds the basic wind velocity specified in American National Standard Institute (ANSI) Standard A58.1[2] for the geographical location of the WIPP facility.

The design wind velocity for Design Class III structures shall be 91 mi/hr (146.5 km/hr), with a 50-year mean recurrence interval, except for the Support Building and Exhaust Filter Building, which is 99 mi/hr (159.3 km/hr) with a 100-year mean recurrence interval.

3.2.1.1 Vertical Velocity Distribution and Gust Factors

The vertical velocity distribution used shall be as given in Section 6 of ANSI Standard A58.1[2] using exposure C (flat, open country; flat, open coastal belts; and grassland) for the design wind velocity, including the appropriate gust factors. The ANSI standard contains the effective wind velocity pressures for the overall design of structures in Table 5 of the standard. The ANSI standard contains the effective wind velocity pressures for the design of parts and portions of structures in Table 6, and the effective wind velocity pressures for calculating internal pressures in Table 12.

3.2.1.2 Determination of Applied Forces

The procedures used to convert the wind velocity into applied forces on structures shall be as outlined in ANSI Standard A58.1.[2] Velocity pressures shall be determined from the tables using the design wind velocity. The design wind loads shall be obtained by multiplying the effective velocity pressures by the appropriate pressure coefficients in Sections 6.5 through 6.9, in accordance with Section 6.4 of ANSI Standard A58.1.[2] The design wind loads for enclosed structures are shown in Table 3.2-1.

3.2.2 Tornado Loadings

Tornado loadings applicable to certain Design Class II surface facilities are described in the following sections. For purposes of structural design, the effects of a tornado are described in Section 3.0 of Bechtel topical report BC-TOP-3-A.[3]

3.2.3 Applicable Design Parameters

Tornado-resistant structures shall be designed for tornado loadings (not coincident with any accident condition or earthquake) as outlined in Sections 3.3 and 3.4 of BC-TOP-3-A.[3] The parameters used for the DBT are the result of a site-specific wind and tornado study for the WIPP facility,[1] and the loadings shall be calculated based on the following tornado characteristics:

Maximum wind speed (Including effects of suction vortices)	183 mi/hr	(294.5 km/hr)
Translational velocity	41 mi/hr	(66 km/hr)
Tangential velocity	124 mi/hr	(199.6 km/hr)
Radius of maximum wind	325 ft	(99 m)
Pressure drop	0.5 lb/in^2	(0.035 kg/cm^2)
Rate of pressure drop	0.09 lb/in^2/s	(0.006 kg/cm^2/s)

The above tornado parameters are based on a 1,000,000-year recurrence period, and the maximum wind speed shall be the vector sum of all velocity components.

3.2.3.1 Determination of Forces on Structures

The methods used to convert the tornado wind and atmospheric pressure change into forces and the distribution of these forces across the structures shall be as outlined in Section 3.5 of BC-TOP-3-A.[3] Combinations of loadings are discussed in Section 3.2.11.

The idealized pressure-time function shown in Figure 3.2-1 shall be used to determine the differential pressure loading resulting from atmospheric change. The atmospheric differential pressure, with a maximum value of 0.5 lb/in^2 (0.035 kg/cm^2), tends to force external surfaces of enclosed structures outward.

3.2.3.2 Plant Structures not Designed for Tornado Loads

Structures not resistant to tornados, whose collapse could result in the loss of required function of tornado-resistant structures, or systems that are under tornado loading conditions shall be analyzed for their mode of failure. This is to ensure that such a collapse does not cause any tornado-resistant structure or system to lose its intended function.

3.2.4 Water Level (Surface Flood) Design

The WIPP facility nominal grade elevation is more than 400 ft (122 m) above the probable maximum flood (PMF) level of the Pecos River, and the WIPP facility is separated from the river by about 12 mi (19.3 km) of gradually rising land. Since there are no perennial or intermittent streams near the WIPP facility that have the potential for sustained flooding of the site, neither buoyancy nor static water forces due to flood elevations shall be considered in the WIPP facility design.

3.2.4.1 Phenomena Considered in Design Load Calculations

Phenomena such as flood currents or wind-induced waves shall not apply, because the grades for the WIPP facility structures are more than 400 ft (122 m) above the PMF level on the Pecos River, and none of the local drainage ways has the potential for sustained flooding of the WIPP facility.

3.2.4.2 Flood Force Application

As stated previously, the WIPP facility structures are above the PMF level and are not subjected to flood loadings.

3.2.4.3 Flood Protection

Protection against the PMF level on the Pecos River shall not be required for WIPP facility SSCs.

The on-site storm drainage system shall be based on a minimum 10-year, 24 hour frequency storm. Culverts shall be designed to discharge a 25-year storm, utilizing the head available at entrance. At on-site roads, the static head shall not exceed the subgrade. Minimum design concentration time shall be five minutes. The site drainage system shall include and provide the following:

- Peripheral ditches
- Culverts
- Ditches
- Under drains

The design shall be such that local probable maximum precipitation does not flood any of the on-site facilities of Design Class IIIA and higher. Onsite stormwater retention basins have a design capacity to hold two consecutive 10-year, 24 hours storm events.

3.2.5 Groundwater Design

3.2.5.1 Groundwater Forces

Forces exerted by water in the geological formations overlying the salt shall be considered as lateral loads on the shafts caused by the piezometric heads in the water-bearing zones of the Rustler Formation, and shall be sealed to prevent seepage into the salt formations.

Surface water shall be prevented from entering the shafts by sloped shaft collars.

3.2.5.2 Design Loads

Groundwater forces shall be combined with other types of loads for structural design, as described in Section 3.2.11, Combined Load Criteria.

3.2.5.3 Protection From Groundwater

Shaft linings and structures shall minimize water seepage, and shall be designed against hydrostatic pressure since the water-bearing unit above the waste disposal level will not be drained. Chemical seals shall be constructed, as required, around the shafts, under the water-bearing unit area to minimize water migration to lower elevations, and water collection rings shall be provided to collect seepage that might enter through the shaft lining.

Since there are no significant sources of moisture or groundwater in the Salado Formation underground mined area, no additional humidity or moisture controls beyond those described shall be required.

3.2.6 Protection Against Dynamic Effects

To prevent plant equipment failures from generating internal missiles, rotating equipment shall be designed, wherever possible, to preclude that possibility. Equipment identified as potential missile sources shall be arranged and oriented so that any missile generated would impact a structure or barrier capable of withstanding that impact, preventing damage to Design Class II SSCs.

3.2.7 Seismic Design

Design Class II confinement SSCs shall be designed to withstand a Design Basis Earthquake (DBE). The DBE, based on a 1,000-year earthquake has been established through a seismic study of the WIPP facility region, as discussed in Chapter 2. This section summarizes the seismic input from Chapter 2, and describes the methods and procedures of seismic analysis.

3.2.7.1 Input Criteria

The maximum ground acceleration for the DBE is 0.1g in both horizontal and vertical directions, and shall be used in analysis and design of surface facilities and equipment. As described in Chapter 2, several WIPP facility region seismic zone characterizations have been taken into account in establishing the maximum ground motion.

3.2.7.1.1 Design Response Spectra

The design response spectra for horizontal and vertical components of the DBE shown in Figure 3.2-2 and Figure 3.2-3, are based on a statistical analysis of the existing strong ground motion earthquake records of various durations, recorded at sites having various geologic conditions and located at various epicentral distances.

3.2.7.1.2 Derivation of Design Response Spectra

Synthetic earthquake time histories shall not be required for seismic design of the WIPP facility since actual response spectra were used.

3.2.7.1.3 Critical Damping Values

The range of damping values (percent of critical) for SSCs shall be as given in Sections 2.2 and 3.2 of BC-TOP-4-A,[4] and are shown in Table 3.2-2.

Damping values of soil and foundation materials are determined by laboratory tests.

The formulas used to determine the equivalent foundation damping coefficient shall be as given in Section 3.3 of BC-TOP-4-A.[4] They are used when a lumped parameter approach is appropriate for soil structure interaction considerations.

3.2.7.1.4 Soil Supported Structures

The Design Class II surface structures shall be constructed either directly on caliche or compacted sandstone, or on a sand layer above the caliche. The foundation support materials shall be designed to withstand the pressures imposed by the appropriate loading combinations, with an adequate safety factor.

3.2.7.1.5 Soil-Structure Interaction

Structural systems affected by soil-structure shall be analyzed, as applicable, in accordance with Section 3.3 and Appendix D of BC-TOP-4-A.[4]

3.2.7.2 Seismic System Analysis

The structures and systems shall be designed for either DBE or Uniform Building Code[5] (UBC) earthquake loads, as specified in Section 3.1.3.

3.2.7.2.1 Seismic Analysis Method

Analytical methods used for seismic analysis shall be as described in Sections 1.0 and 3.0 of BC-TOP-4-A.[4]

The structural mode shapes and frequencies shall be calculated for the models for the fixed base cases. Whenever appropriate, foundation structure interaction shall be analyzed in accordance with the methods given in Section 3.3 of BC-TOP-4-A.[4] A response spectrum analysis shall be conducted for the structure using the above calculated parameters. The results of the analysis shall include acceleration, displacements, shears, moments, and other related information necessary for structural design. Design allowables shall be as given in Section 3.2.11 of this document, for the various loading combinations including seismic loadings.

The simplified method of analysis shall be used for frame type structures in lieu of the analytical method described above. The simplified method shall be acceptable for verifying the structural integrity of frame structures that can be represented by a simple model. No determination of natural frequencies shall be made, but rather the design acceleration shall be assumed to be 1.5 times the peak of the required response spectrum.

3.2.7.2.2 Methods Used to Couple Soil with Seismic Structures

If a detailed design and soil investigation determines that a structure is founded on a sand layer of a depth comparable to its plane dimension, foundation impedances based on elastic half-space theory shall be developed and used to account for the soil-structure interaction as described in Section 3.3.1, of BC-TOP-4-A.[4]

3.2.7.2.3 Development of Floor Response Spectra

A simplified method shall be used to generate the approximate floor response spectra without the need of performing a time history analysis of structures. The method used shall be as developed by Tsai and Tseng,[6] which derives spectrum peak envelopes from the design response spectra shown in Figure 3.2-2 and Figure 3.2-3. Subsequently, the floor response spectra for equipment design shall be developed using these peak envelopes and the frequencies of the soil-structure systems.

3.2.7.2.4 Effects of Variations on Floor Response Spectra

Section 5.2 of BC-TOP-4-A[4] describes the various considerations that shall be used in the seismic analyses, including the effects on floor response spectra of expected variations of structural properties, damping, soil properties, and foundation-structure interaction. These calculations shall include the details of the effects of variations on the floor response spectra.

3.2.7.2.5 Use of Constant Vertical Load Factors

The method of analysis used for both the vertical and horizontal directions shall be the re-spectrum method. The induced forces, moments, and resulting stresses due to motions in the vertical and the two horizontal directions shall be combined by the square root of the sum of the squares (SRSS) technique.

3.2.7.2.6 Method Used to Account for Torsional Effects

Torsional effects, if significant, shall be included in the horizontal models at locations of major mass and/or structural eccentricity. The techniques in Section 3.2 and Appendix C of BC-TOP-4-A[4] shall be used to account for torsional effects.

3.2.7.2.7 Analysis Procedure for Damping

The analysis procedure employed to account for damping in various elements of the model of a coupled system shall be as described in Sections 3.2 and 3.3 of BC-TOP-4-A,[4] including the criteria for evaluating the composite model damping of the system, and accounting for the damping of various structural elements and foundations.

3.2.7.3 Seismic Subsystem Analysis

This section covers the seismic analysis of Design Class II equipment and subsystems essential to confinement.

3.2.7.3.1 Determination of the Number of Earthquake Cycles

During the plant life, one DBE shall be assumed to occur. For the DBE, about 10 maximum stress cycles shall be assumed to be induced in the SSCs, and the SSCs shall be designed on the basis of analytical results. In general, the design of structures and equipment for the WIPP facility shall not be fatigue controlled since most stress and strain changes occur only a small number of times, or produce only minor stress-strain fluctuations or both. Earthquake and Design Basis Accident (DBA) full-design strains occur too infrequently and with too few cycles to generally require fatigue design of structures and equipment.

3.2.7.3.2 Basis for the Selection of Forcing Frequencies

Structural fundamental frequencies shall be calculated in accordance with Section 4.2.1 of BC-TOP-4-A.[4]

3.2.7.3.3 Root-Mean Square Basis

The term "root-mean square basis" used for a combination of modal responses shall be the same equation as SRSS given as follows:

$$Q\ max = (Q_1^{\,2}\ max + Q_2^{\,2}\ max + \ldots + Q_n^{\,2}\ max)^{1/2}, \text{ where } Q\ max = SRSS$$

3.2.7.3.4 Procedure for Combining Modal Responses

The procedure for combining modal responses (shear, moments, stresses, and deflections or accelerations or both) when a response spectrum modal analysis is used, shall be as follows:

- The SRSS method of combining modal responses shall be used, if modes are not closely spaced.
- All significant modes up to 33 Hz shall be used in the analysis; however, the lowest three modes shall always be used. Above 33 Hz the element acts as a rigid body, and the calculations would be trivial.
- Where closely spaced frequencies of two or more modes occur, these modal responses shall be combined in an absolute sum; the resulting sum is treated as that of a pseudo-mode, then combined with the remaining modes by SRSS.

3.2.7.3.5 Significant Dynamic Response Modes

Seismic designs of subsystems (i.e., floor or wall-mounted components, etc.) shall be based on modal analysis by using the appropriate floor response spectra and the procedures in Section 3.2.7.2.3. The static loads equivalent to the peak of the floor spectrum curve shall be used only for: (1) a subsystem that can be idealized as a single degree-of-freedom system, or (2) a multiple degree-of-freedom system whose fundamental frequency is far from all the other natural frequencies. In such cases, only the fundamental mode shall be considered.

3.2.7.3.6 Basis for Computing Combined Response

The basis for the methods used to determine the possible combined (two-component) horizontal and vertical amplified response loading for seismic design of equipment, including the effect of seismic response of the supports, equipment, and structures and components, shall be as described in BC-TOP-4-A.[4]

3.2.7.3.7 Amplified Seismic Responses

The dynamic analysis method used to analyze subsystems shall be as described in Section 3.2.7.2.1.

3.2.7.3.8 Modal Period Variation

The peaks of floor response spectra shall be widened, by an amount to be determined by the procedure given in Section 5.2 of BC-TOP-4-A,[4] on both sides of the peak, to account for modal period variations due to the variation of structural and foundation properties and idealization in mathematical modeling.

3.2.7.3.9 Torsional Effects of Eccentric Masses

The torsional effects of valves and other eccentric masses shall be included.

3.2.7.3.10 Seismic Analysis for Overhead Cranes

All overhead cranes used for waste handling shall have seismic retainer attachments to prevent them from dislodging during a seismic event.

3.2.8 Snow Loadings

Design Class II structures shall be designed for a snow load of 27 lb/ft.^{2} (0.013 kg/cm^2)

The design snow load is derived by using the 100-year recurrence snow load of 10 lb/ft^2 (0.005 kg/cm^2) specified in ANSI Standard A58.1,[2] and by determining the quantity of standing water from winter precipitation required to arrive at a threshold condition.

Roof snow loads shall be calculated by multiplying the design snow load by the appropriate coefficients (C_s) specified in Figure 5, Figure 6, and Figure 7 of ANSI A58.1.[2]

In the combined loading calculations given in Section 3.2.11, the roof snow loads shall be used in place of the minimum roof live load, where such loading is more critical in governing the design.

3.2.9 Equipment and Materials-Derived Loads

Equipment and materials-derived loads in this section are discussed by first defining loading nomenclature, then presenting the loading criteria.

3.2.9.1 Nomenclature

D Dead Load - The dead load shall consist of the weight of the structure, permanent equipment, piping, conduits, cables, and other permanent static loads.

L Live Load - The live load shall consist of uniformly distributed occupancy loads, moving vehicle loads, crane or its related equipment loads, snow and ice loads, and other loads which vary with intensity and occurrence. The minimum uniformly distributed live loads, concentrated loads, and minimum roof live loads shall be those specified in ANSI A58.1,[2] Table 1, Table 2, and Table 3. The live load arrangement design shall use the highest stresses in the supporting members. Structures carrying live loads that can induce dynamic, vibratory, or impact forces shall be designed for those forces, as specified in Section 3.4 of the ANSI A58.1,[2] or as determined by appropriate analysis.

S Snow Load - A snow load shall be used in the design of structures, and shall be applied in accordance with Section 7 of ANSI A58.1.[2] Snow load shall be used instead of roof live load, when such loading is more critical to the design.

W Wind Load - A wind speed of 110 mi/h (176 km/h), with a 1,000-year mean recurrence interval, shall be used in the design of Design Class II structures. A wind speed of 99 mi/hr (158 km/hr), with a 100-year mean recurrence interval, shall be used in the design of the structural portions of the Support Building, Exhaust Filter Building, and Building 412. All other Design Class IIIA and IIIB structures shall be designed for a basic wind speed of 91 mi/hr (145.6 km/hr) with a 50-year mean recurrence interval. Conversion of wind speed to wind pressure shall be per Sections 6.1 thru 6.11 of ANSI A58.1[2] and the DOE Guide for Calculation of Design Wind Pressures,[7] Sections A and B.

W_t Total Tornado Load - The loads generated by the design basis tornado, W_t, shall include the effect of tornado wind and pressure differential. The most critical case of the following combinations governs the design.

W_t = Tornado Wind Load (W_w)
W_t = Tornado Differential Pressure (W_p)
$W_t = W_w + 0.5\ W_p$

E′ Seismic Load - Load generated by the DBE.

F Hydrostatic Load - Vertical liquid pressure shall be considered as dead load with regard to variation in liquid depth.

H Soil Pressure - Structures or parts of structures which retain fills, excluding shafts, shall be proportioned to withstand the lateral soil pressure, as given in the WIPP Soils Design Report - Volume I, DR-22-V-01.[8]

Salt Creep - Provisions shall be made for eliminating or accommodating stresses, deformations, and/or movements in structures, such as brattice walls, bulkheads, etc., adjacent to the salt. An adequate gap shall be provided between the salt and structure to accommodate creep effect. For structures, walls, or bulkheads that require sealing, the gap shall be bridged with a fire-resistant or noncombustible flexible material.

T Thermal Load - Provisions shall be made for stresses, deformations, or movements resulting from variations in temperature. For surface structures, the ambient temperature rise or fall from that at the time of erection, is assumed to be 60°F (15.6°C) for metal structures and 40°F (4.5°C) for concrete or masonry structures. For underground structures, the ambient temperature rise or fall from that at the time of erection is assumed to be 30°F (-1.1°C) for metal structures and 20°F (-7.5°C) for concrete structures.

3.2.10 Thermal Loadings (Salt)

Waste shall be emplaced so thermal loading (heat generation) does not exceed an average of 10 kW/acre (24.7 kW/hectare).[9] Thermal analyses of geologic waste isolation in salt,[9] show that more than 150 kW (142.3 BTU/s) of heat generating waste can be emplaced in an acre of a storage facility without unacceptable impacts on the salt beds or the surrounding environment. However, a conservative design limit of 10 kW/acre (24.7 kW/hectare) shall be established.

3.2.11 Combined Load Criteria

Design Class II confinement structures and supports shall be designed for dead, live, thermal, wind, earthquake, tornado, and soil pressure loads.

The Design Class III structures, and those Design Class II structures and supports not required for confinement, shall be designed in accordance with the UBC.[5]

3.2.11.1 Nomenclature

Nomenclature is defined in Section 3.2.9.1, and additional symbols related to the design of steel and concrete structures shall be defined as follows:

Note: The 33 percent increase in allowable stresses for concrete and steel due to seismic or wind loadings shall not be permitted.

S For steel structures, S shall be the required strength based on the elastic design method and the allowable stresses defined in Part I of the American Institute of Steel Construction (AISC) Specification.[10]

U For concrete structures, U shall be the required strength to resist the design loads. This is based on the strength design method described in America Concrete Institute Standard 318-77.[11]

3.2.11.2 Load Combinations

3.2.11.2.1 Design Requirements

All structures shall be designed to have strengths at all sections at least equal to the structural effects of the design loads as listed in Table 3.2-3 in such combinations as shown below.

<u>Design Class II - Reinforced Concrete Structures</u>

$U = 1.4D + 1.4F + 1.7L + 1.7H$
$U = 1.4D + 1.4F + 1.7L + 1.7H + 1.7W$
$U = 1.05D + 1.05F + 1.3L + 1.3H + 1.3T$
$U = 1.05D + 1.05F + 1.3L + 1.3H + 1.3W + 1.3T$
$U = D + F + L + H + T + E'$
$U = D + F + L + H + T + W_t$

Design Class II - Steel Structures

$S = D + L$
$S = D + L + W$
$1.5S = D + L + T$
$1.5S = D + L + T + W$
$1.6S = D + L + T + E'$
$1.6S = D + L + T + W_t$

Where the structural effects of differential settlement may be significant, it shall be included with the dead load (D) in load combination. An estimation of this effect shall be based on a realistic assessment of such effect occurring in service. When any load reduces the effects of other loads, the corresponding coefficient for that load shall be taken as 0.9, if it can be demonstrated that the load is always present or occurs simultaneously with the other loads, else the coefficient for that load shall be taken as zero.

Design Class IIIA - Reinforced Concrete and Steel Structures

Design Class IIIA structures shall be designed in accordance with the provisions of UBC,[5] except that the design loads shall comply with ANSI A58.1,[2] unless otherwise specified in Table 3.2-3.

Design Class IIIB - Reinforced Concrete, Steel, and Masonry Structures

Design Class IIIB structures shall be designed in accordance with the provisions of UBC,[5] except that the design loads shall comply with ANSI A58.1,[2] unless otherwise specified in Table 3.2-3.

Design Class IIIB - Pre-engineered Metal Building Structures

The pre-engineered metal building shall be designed in accordance with the Metal Building Systems Manual of Metal Building Manufacturers Association,[12] except that the design loads shall comply with ANSI A58.1[2] with the following exceptions:

Wind load shall be calculated based on a basic wind speed, V, of 91 mi/h (145.5 km/h). For building height less than 30 ft (9.15 m), the effective velocity pressures q_F, q_M, and q_P in ANSI A58.1,[2] shall be reduced using the following formulas.

$q_F = 0.00268\ V^2\ (H/30)^{2/7}$
$q_M = 0.00246\ V^2\ (H/30)^{2/7}$
$q_P = 0.00377\ V^2\ (H/30)^{2/7}$

Where H = Mean height of the roof or 15 ft (4.6 m), whichever is greater.

Seismic load shall be in accordance with the requirements set forth in UBC,[5] Seismic Zone No. 1.

Snow load shall be calculated based on a basic snow load of 10 lb/ft^2 (0.005 kg/cm^2).

3.2.11.2.2 Minimum Factors of Safety with Respect to Overturning, Sliding, and Floatation

In addition to the above load combinations, the following combinations and factors of safety shall apply to structures when being checked for overturning, and sliding:

Minimum Factors of Safety

Load Combination	Overturning	Sliding
D+H+W	1.5	1.5
D+ H+E′	1.1	1.1
D+ H+W_t	1.1	1.1

Where Section 3.2.9.1 describes H, D, E′, W, and W_t except that, for conservatism, only the weight of a structure and the components permanently attached to it shall be accounted for in D. The factor of safety against floatation, defined as the ratio of dead load divided by the hydrostatic uplift, shall be 1.1 minimum.

3.2.12 Soil Erosion Control

The design control measures to minimize soil erosion and to control sediment-laden runoff at the WIPP facility shall be in accordance with the amended Water Control Commission regulations, Water Quality Control Commission, State of New Mexico, and applicable federal regulations.

References for Section 3.2

1 The University of Chicago, SMPR Research Paper No. 155, A Site Specific Study of Wind and Tornado Probabilities at the WIPP Site in Southeast New Mexico, UN000075, February 1978.

2 ANSI A58.1-1972, American National Standard Building Code Requirements for Minimum Design Loads in Buildings and other Structures.

3 BC-TOP-3-A, Tornado and Extreme Wind Design Criteria for Nuclear Power Plants, August 1974.

4 BC-TOP-4-A, Seismic Analyses of Structures and Equipment for Nuclear Power Plants, November 1974.

5 Uniform Building Code, 1979 edition.

6 Tsai and Tseng, Standardized Seismic Design Spectra for Nuclear Plant Equipment, Nuclear Engineering and Design, Vol. 45, UN000169, 1978.

7 DOE Guide for Calculation of Design Wind Pressures.

8 DR-22-V-01, WIPP Soils Design Report, Volume I, Bechtel, Inc., 1979.

9 Y/OWI/SUB-76/07220, The Selection and Evaluation of Thermal Criteria for a Geological Waste Isolation Facility in Salt, Science Applications, Incorporated, Oak Ridge, TN, September 1976.

10 American Institute of Steel Construction, Specification for Design, Fabrication, Erection of Structural Steel for Buildings, November 1978.

11 American Concrete Institute Standard 318-77, Building Code Requirement for Reinforced Concrete, December 1977.

12 Metal Building Systems Manual of Metal Building Manufacturers Association, Cleveland, OH.

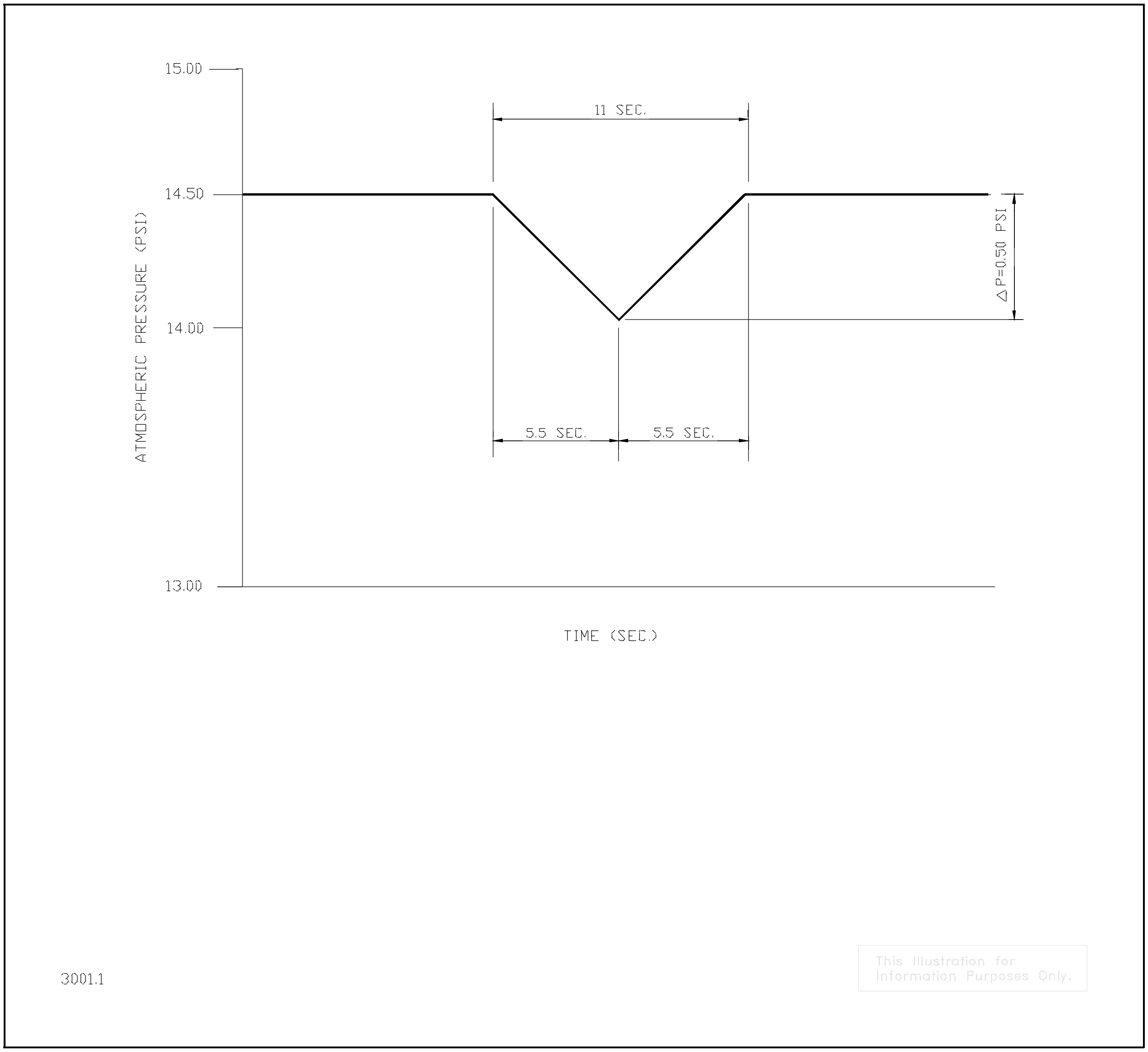

Figure 3.2-1, Idealized Function of Atmospheric Pressure Change vs. Time

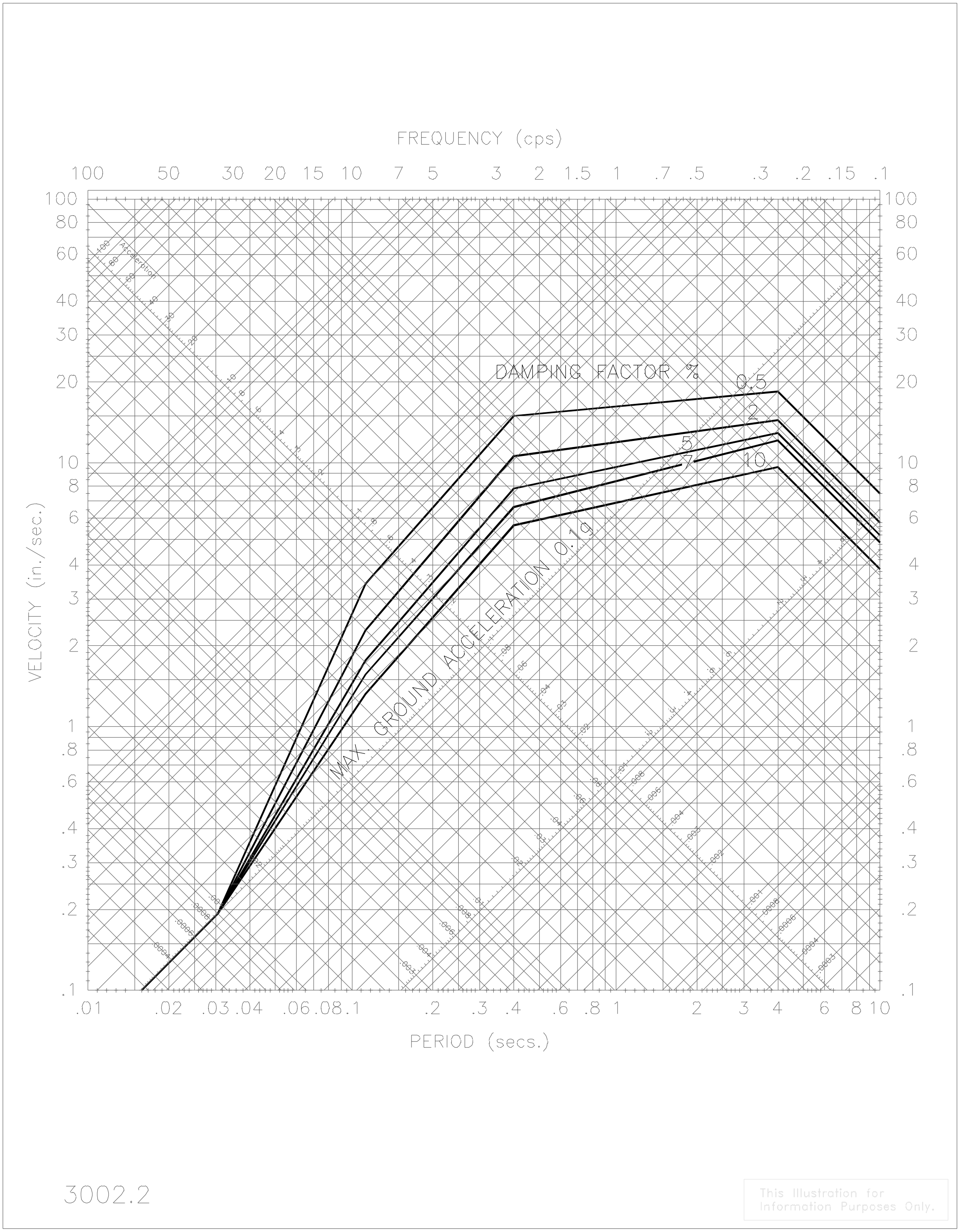

Figure 3.2-2, Horizontal Design Response Spectra

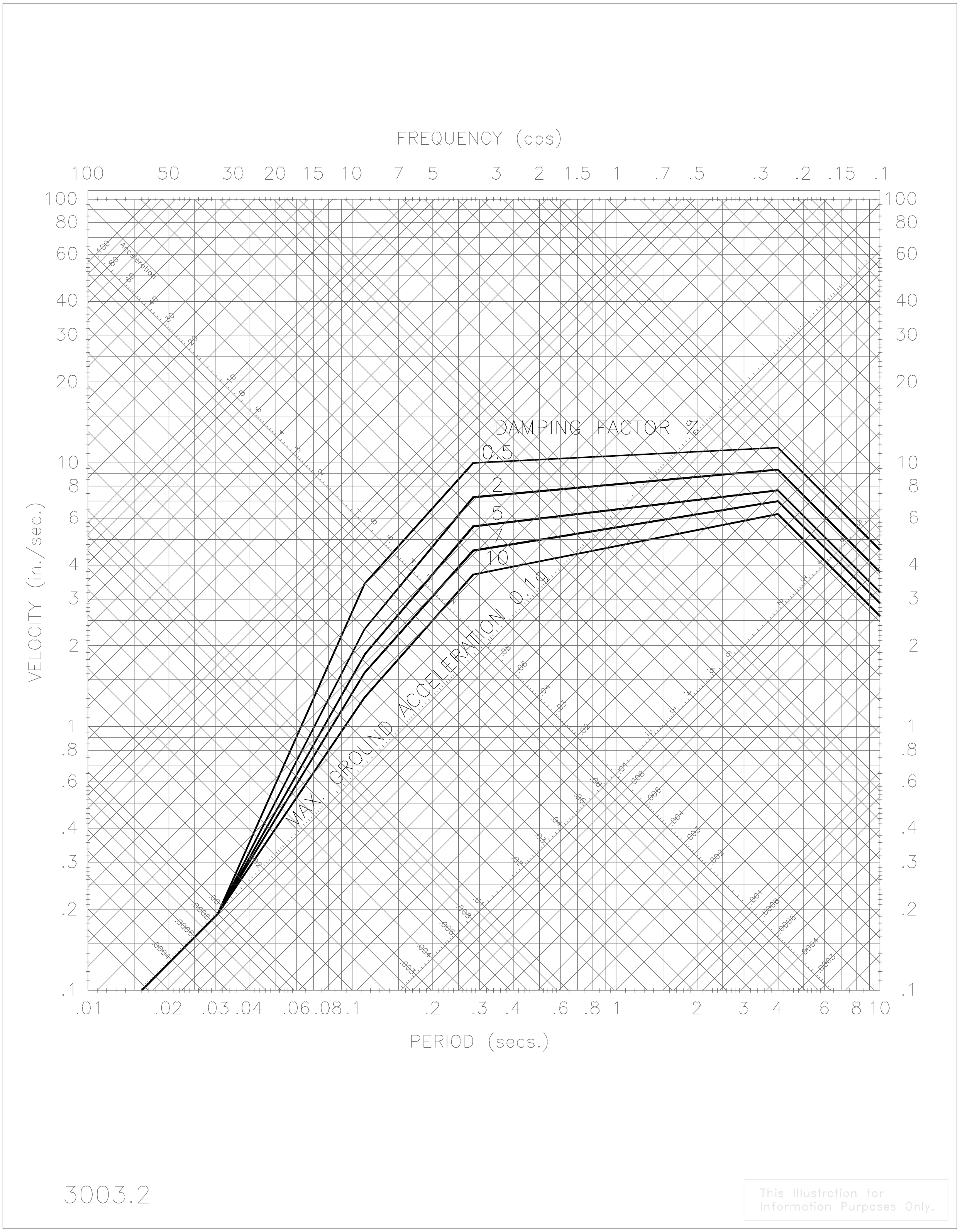

Figure 3.2-3, Vertical Design Response Spectra

Table 3.2-1, Design Wind Load (Enclosed Structures Subjected to 110 mi/h Wind)

	Height, ft (m)	**Windward, lb/ft^2 (kg/m$^{2)}$)**	**Leeward, lb/ft^2 (kg/m^2)**	**Roof, lb/ft^2 (kg/m^2)**	**Sides, lb/ft^2 (kg/m^2)**	**Limitations**
External	0-29 (0-8.8)	+26(+127)	-19 (-93)	-22 (-107)	-22 (-107)	Height/Width< 2.5
	30-49 (9.1-14.9)	+35(+171)	-26 (-127)	-25 (-122)	-25 (-122)	Height/Length <2.5
	50-99 (15.2-30.2)	+40(+195)	-30 (-146)	-35 (-171)	-35 (-171)	
	100-149 (30.5-45.4)	+45(+220)	-34 (-166)	-39 (-190)	-39 (-190)	
Internal Pressure	0-29 (0-8.8)	-9 (-44)	-9 (-44)	-9 (-44)	-9 (-44)	No Openings
	30-49 (9.1-14.9)	-10 (-49)	-10 (-49)	-10 (-49)	-10 (-49)	
	50-99 (15.2-30.2)	-12 (-59)	-12 (-59)	-12 (-59)	-12 (-59)	
	100-149 (30.5-45.4)	-14 (-68)	-14 (-68)	-14 (-68)	-14 (-68)	
Internal Vacuum	0-30 (0-9.1)	+9 (+44)	+9 (+44)	+9 (+44)	+9 (+44)	No Openings
	30-50 (9.1-15.2)	+10 (+49)	+10 (+49)	+10 (+49)	+10 (+49)	
	50-100 (15.2-30.5)	+12(+59)	+12(+59)	+12(+59)	+12(+59)	
	100-150 (30.5-45.7)	+14(+68)	+14(+68)	+14(+68)	+14(+68)	

Sign convention:
- \+ Inward force
- \- Outward force

Table 3.2-2, Damping Values of SSCs for Design Basis Earthquake

Structure or Component	Damping Value % of Critical Damping
Welded steel structures	4
Bolted steel structures	7
Reinforced concrete structures	7
Equipment and large diameter piping systems, pipe diameter greater than 12 in (30.5 cm)	3
Small diameter piping systems, diameter equal to or less than 12 in (30.5 cm)	2
Prestressed concrete structures	5

Table 3.2-3, Design Loads for Surface Structures[1]

DESIGN CLASS	STRUCTURE	SEISMIC DBE	SEISMIC UBC	TORNADO DBT	SNOW lb/ft^2	WIND mi/hr
Class II	Waste Handling Building	X[2]		X	27	110
Class II	Station A	X		X	27	110
Class IIIA	Support Building	(3)	X	(3)	10	99
Class IIIA	Exhaust Filter Building		X		10	99
Class IIIA	Building 412	(3) X		(3)	27	110
Class IIIB	Warehouse/Shops Building		X		10	91
Class IIIB	Water Pumphouse		X		10	91
Class IIIB	SH Shaft Hoist House & Electrical Room		X		10	91

Notes:
(1) For definition of various loads, see Section 3.2.9.1.
(2) "X" indicates applicable load.
(3) The main lateral force resisting members of the Support Building and Building 412 shall be designed for DBE and DBT to protect the Waste Handling Building from structural failure.

3.3 Safety Protection Criteria

3.3.1 Confinement Requirements

The regulatory requirements for confinement applicable to the WIPP are defined in DOE Order O420.1,[1] Facility Safety. Confinement systems for the WIPP shall be designed to the pertinent provisions of DOE Order O 420.1,[1] Facility Safety, and shall accomplish the following:

- Minimize the spread of radioactive and other hazardous materials within the unoccupied process areas

- Prevent, if possible, or minimize the spread of radioactive and other hazardous materials to occupied areas

- Minimize the release of radioactive and other hazardous materials in facility effluents during normal operation and anticipated operational occurrences

- Limit the release of radioactive and other hazardous materials resulting from Design Basis Accident (DBAs) including severe natural phenomena and man-made events, in compliance with the guidelines contained in DOE Order O 420.1,[1] Section 4.1.1.2, Design Requirements

The ventilation system of a confinement system shall maintain airflow into the containment rooms or areas of a building to ensure that the airflow is from non-contaminated areas to potentially contaminated areas, and then to areas potentially at higher levels of contamination.

Confinement systems for the WIPP shall be designed to specific provisions of DOE O 420.1,[1] Facility Safety, as follows:

- The primary confinement shall consist of the waste containers

- The secondary confinement system shall consist of the buildings/structures and associated ventilation systems that enclose the primary confinement, and which are identified in Section 4.4

- The tertiary confinement shall be the natural geologic setting

The secondary confinement shall be designed to ensure that it can withstand the effects of severe natural phenomena and man-made events, including DBAs, and remain functional to the extent that the guidelines in DOE Order O 420.1,[1] Section 4.1.1.2, Design Requirements, are not violated.

3.3.2 Fire Protection

The WIPP fire protection system shall be designed in conformance with the design criteria set forth in DOE Order O 420.1, Facility Safety,[1] and 30 CFR 57.[2] The fire protection system design shall conform to provisions of the following codes and standards, as applicable.

- National Fire Codes of the National Fire Protection Association (NFPA)

- Loss prevention data sheets of Factory Mutual Research Corporation

- Uniform Building Code (UBC)

3.3.3 Radiological Protection

The WIPP facility shall use design considerations that assure and maintain radiation exposures as low as reasonably achievable (ALARA) to the general public and workers. These considerations shall be consistent with the intent of the Radiological Control Manual, DOE/EH-0256T,[3] 10 CFR 835,[4] and recommendations of Nuclear Regulatory Commission (NRC) Regulatory Guides 8.8[5] and 8.10.[6]

3.3.3.1 Controlled Areas

Entrance to and exit from controlled areas within the WIPP facility shall be implemented in accordance with the WIPP Radiation Safety Manual.[7]

3.3.3.2 High Radiation Areas

All high radiation areas shall be designed with access control and warning devices in accordance with the requirements set forth in DOE/EH-0256T[3] and 10 CFR 835.502.[4]

3.3.3.3 Shielding

The shielding design basis shall be to limit the maximum exposure to an individual worker to one-fifth of the annual occupational external exposure limits specified in 10 CFR 835.[4] Within the design basis, personnel exposures shall be maintained ALARA. Specifically, the shielding shall be designed to limit the occupational exposure during normal operation to the administratively selected limit of 1 rem/yr (10 mSv/yr) Total Effective Dose Equivalent (TEDE) for operating personnel.

The integrity, design, and performance of concrete shielding shall be assured by adherence to the requirements and practices recommended in ANSI N 101.6-1972, Concrete Radiation Shields.[8]

3.3.3.4 Nuclear Criticality Safety

Criticality safety requirements shall be considered for the WIPP in accordance with DOE O 420.1.[1] The basic elements and control parameters of programs for nuclear criticality invoked by the DOE order are the American Nuclear Society's ANSI/ANS nuclear criticality safety standards listed below:

ANSI/ANS-8.1[9]	Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors
ANSI/ANS-8.3[10]	Criticality Accident Alarm System
ANSI/ANS-8.5[11]	Use of Borosilicate-Glass Raschig rings as a Neutron Absorber in Solutions of Fissile Material
ANSI/ANS-8.7[12]	Guide for Nuclear Criticality Safety in the Storage of Fissile Materials
ANSI/ANS-8.15[13]	Nuclear Criticality Control of Special Actinide Elements
ANSI/ANS-8.19[14]	Administrative Practices for Nuclear Criticality Safety

3.3.4 Industrial and Mining Safety

The WIPP surface SSCs shall be primarily designed to comply with the occupational safety and health program requirements of DOE Order 5483.1A,[15] and the Occupational Safety and Health Administration requirements of 29 CFR 1910[16] and 29 CFR 1926[17] to minimize the potential for industrial accidents.

The WIPP hoists and underground systems and equipment shall be primarily designed in conformance with the requirements of Mine Safety and Health Administration 30 CFR 57[2] and the New Mexico Mine Safety Code For All Mines.[18]

References for Section 3.3

1 DOE O 420.1, Facility Safety.

2 30 CFR 57, Safety and Health Standards - Underground Metal and Nonmetal Mines, 1977.

3 DOE/EH-0256T, Radiological Control Manual, June 1992.

4 10 CFR 835, Occupational Radiation Protection, December 1993.

5 Nuclear Regulatory Commission Regulatory Guide 8.8, Information Relevant to Ensuring Occupational Radiation Exposure As Low As Is Reasonably Achievable (Nuclear Power Reactors), March 1979.

6 Nuclear Regulatory Commission Regulatory Guide 8.10, Operating Philosophy for Maintaining Occupational Radiation Exposure As Low As Is Reasonably Achievable, September 1975.

7 WP 12-5, WIPP Radiation Safety Manual.

8 ANSI N101.6-1972, Concrete Radiation Shields, December 1972.

9 ANSI/ANS-8.1, Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors, 1983.

10 ANSI/ANS-8.3, Criticality Accident Alarm System, 1986.

11 ANSI/ANS-8.5, Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material, 1986.

12 ANSI/ANS-8.7, Guide for Nuclear Criticality Safety in the Storage of Fissile Materials, 1975.

13 ANSI/ANS-8.15, Nuclear Criticality Control of Special Actinide Elements, 1981.

14 ANSI/ANS-8.19, Administrative Practices for Nuclear Criticality Safety, 1984.

15 DOE Order 5483.1A, Occupational Safety and Health Program for DOE Contractor Employees at Government Owned Contractor Operated Facilities, June 22, 1983.

16 29 CFR 1910, Occupational Safety and Health Standards, 1970.

17 29 CFR 1926, Safety and Health Regulations for Construction, 1979.

18 New Mexico Institute of Mining Technology, New Mexico Safety Code for All Mines, 1990.